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EXCHANGE



A STUDY OF THE EXCITING POWER FOR  
FLUORESCENCE OF THE DIFFERENT  
PARTS OF THE ULTRAVIOLET  
SPECTRUM

A THESIS

PRESENTED TO THE FACULTY OF THE GRADUATE SCHOOL  
OF CORNELL UNIVERSITY FOR THE DEGREE OF  
DOCTOR OF PHILOSOPHY

BY

LELAND JAYNES BOARDMAN

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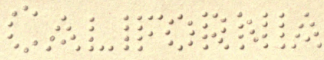
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EXCHANGE





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# A STUDY OF THE EXCITING POWER FOR FLUORESCENCE OF THE DIFFERENT PARTS OF THE ULTRAVIOLET SPECTRUM.

## A STUDY OF THE EXCITING POWER FOR FLUORESCENCE OF THE DIFFERENT PARTS OF THE ULTRAVIOLET SPECTRUM.

BY LELAND JAYNES BOARDMAN.

### SYNOPSIS.

*Intensity of Fluorescence as a Function of Wave-length of Exciting Light, 0.55 to 0.2  $\mu$ .*—The purpose of the experiment was to determine what wave-lengths are effective in excitation and what relations exist between these wave-lengths and the corresponding absorption and fluorescence spectra. Light from a source giving a continuous spectrum was dispersed by means of a quartz spectrograph and allowed to fall on the substance to be studied which was spread on a flat surface. Then the parts of the spectrum which excited fluorescence were observed or photographed by means of the fluorescent light. A preliminary study of seventy substances showed that all the oxides (20) and simple chlorides (8) tested were not excited, a few substances (7) including zinc silicate, zinc sulphate and cadmium phosphate fluoresced faintly, a few responded well (anthracene, eosin, fluorescein, phenolphthalein, calcium tungstate, and phosphorescent willemite), while the uranyl compounds (20) fluoresced strongly. For the last group the effective spectrum extended from 0.55 to 0.35  $\mu$  only, while for the others it extended continuously to 0.2  $\mu$  except in the case of four substances for which light from 0.35 to 0.325 was ineffective. *Excitation band spectrum for twelve uranyl compounds* was determined by measuring the density of the plates as a function of the wave-length by means of a sensitive photoelectric spectrophotometer. Some curves are reproduced and the wave-numbers corresponding to from 35 to 105 maxima for each compound are given. *Comparison with absorption spectra* shows close agreement, an absorption band corresponding to an excitation band in every case. This relation had previously been found by Howe to hold for phosphorescent sulphides.

*Absorption Spectrum of Twelve Uranyl Compounds, from 0.55 to 0.32  $\mu$ .*—Because of the correspondence noted above the excitation bands may be taken to be absorption bands and thus the known absorption spectrum be considerably extended toward both the red and ultraviolet. Comparison of these bands with the fluorescence spectrum indicates clearly many new reversing regions where the fluorescent light obscures the absorbing effect. These are listed.

### INTRODUCTION.

THE purpose of this investigation is to study the behavior of different portions of the ultraviolet spectrum as regards the ability of exciting fluorescence. The major part of previous work in fluorescence has been confined to a study of the fluorescence and absorption spectra of various materials and the relations between the two. This enables one to describe the phenomena, or state what happens as the result of the mechanism producing fluorescence. It also throws some light on the nature of the mechanism itself.



It seemed probable that something could also be learned about this mechanism by studying the means by which it is set in operation: in other words by studying the conditions and means by which fluorescence is excited. As a part of this problem it is of interest to determine what wave-lengths are effective in excitation and what relations exist between the excitation, absorption, and the fluorescence spectra. Almost the only work that has been done along this line is that of Stokes,<sup>1</sup> and, for a certain group of materials, the work of Lenard.<sup>2</sup>

The method of the present investigation is similar to that used by Stokes. Quartz was however used in place of glass, and better sources of ultraviolet light were employed.

Fig. 1 shows the arrangement of the apparatus. Light from the source *S* passed through a spectrograph, and then fell upon the fluorescent substance mounted in the plane of the plate-holder of the spectrograph at *A*.

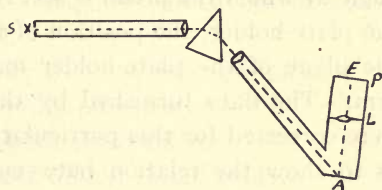


Fig. 1.

With the room darkened the fluorescence was studied for color and relative intensity by the eye at *E*. For more accurate study a photograph was taken by means of a camera lens *L* and a plate at *P*. In this way the exciting power of any region of the ultraviolet light was easily determined, since the dispersed light fell immediately upon the specimen spread out to intercept the entire beam of light.

It was necessary to use a light source which gives a continuous ultraviolet spectrum as free as possible from lines or bands. An electric spark under water was quite satisfactory for a large range of the ultraviolet spectrum. Other sources of light could be used to better advantage however in the visible and near ultraviolet region, since it was very difficult to maintain a spark in water for a sufficiently long time to give a proper exposure for the regions of weak fluorescence. Some photographs were however obtained by long excitation by the spark. By the method of producing the under-water spark used in this work, which is described in another paper soon to be published, it was possible to maintain a vigorous spark discharge 8 mm. in length for half an hour in distilled water, by means of a Tesla coil operated by a transformer of one kilowatt capacity.

It was found that a 400 c.p. nitrogen-filled glass-bulb Mazda lamp gave sufficient intensity in the near ultraviolet, and this was used when

<sup>1</sup> Stokes, Phil. Trans., p. 463, 1852.

<sup>2</sup> Lenard, P. Ueber Lichtemission und deren Erregung. Annalen der Physik, 31, p. 641, 1910.

possible because of its greater convenience. For somewhat shorter wavelengths a similar lamp with a quartz bulb was used.

Two spectrographs were used: the Fuess type, which gives a spectrum about 5 cm. long, range 580  $m\mu$  to 200  $m\mu$ , and a Hilger instrument which gives five regions (5 settings) of the spectrum with a total length of about 30 cm., range 800  $m\mu$  to 205  $m\mu$ . This spectrograph, which proved to be excellent for the purpose, is constructed so that five adjustments of its parts can be made for each of the five ranges or parts of the spectrum. The ranges are: 800 to 400  $m\mu$ , 400 to 305, 305 to 255, 255 to 225 and 225 to 205. The five adjustments are: position of collimating lens, angle at which the prism is set, the angular position of the arm carrying the plate-holder, the position of the objective lens, and the angle which the plane of the plate-holder makes with the axis of the plate-holder arm. The data furnished by the makers for the various adjustments were corrected for this particular instrument and plotted in such a way as to show the relation between each variable and the corresponding range. It was found that practically linear relations existed, so that it was possible to set for any intermediate range desired by merely interpolating between the given settings. A split quartz prism was used.

#### PRELIMINARY STUDY.

A visual study of a great number of substances was made in order to find out what parts of the ultraviolet spectrum were most capable of exciting fluorescence, and also what substances respond best to such excitation, and were therefore suitable for further study. The Fuess spectrograph was mounted in such a way as to make the plane of the plate-holder horizontal. The substance was spread out on a piece of glass or stiff paper and held in the plane of the plate-holder. The following substances were examined in this way, a record being made in each case of the amount and position of the fluorescence excited by the ultraviolet *only* (since the dispersion in this region was good whereas the visible part was very narrow). The uranyl compounds exhibited the strongest fluorescence. They are given in the order of relative intensity, the first being the brightest.<sup>1</sup>

Rubidium uranyl nitrate,	Lead uranyl acetate,
Rubidium uranyl sulphate,	Ammonium uranyl nitrate,
Potassium uranyl sulphate,	Mercury uranyl acetate,
Potassium uranyl nitrate,	Calcium uranyl acetate,
Potassium uranyl chloride,	Strontium uranyl acetate,

<sup>1</sup> The following uranyl compounds were found to fluoresce most strongly under x-ray excitation: Rubidium uranyl nitrate, rubidium uranyl sulphate, cesium uranyl chloride and lithium uranyl acetate.



Ammonium potassium uranyl chloride,	Uranyl acetate,
Cesium uranyl chloride,	Sodium copper uranyl acetate,
Lithium uranyl acetate,	Silver uranyl acetate,
Cadmium uranyl acetate,	Uranyl tellurate,
Barium uranyl acetate,	Thanos uranyl sulphate.

Other substances responding well to ultraviolet excitation were:

Anthracene,	} { variable but continuous excitation between 550 and 200 m $\mu$ .
Phenolphthalein,	
Calcium tungstate,	} { excitation between 550 and 350 m $\mu$ and between 325 and 225 m $\mu$ approximately.
Phosphorescent willemite,	
Fluorescein,	} { Last two substances dissolved in water or alcohol.
Eosin,	

The following substances fluoresced faintly by ultraviolet excitation:

CaC <sub>2</sub> O <sub>4</sub> ,	Cadmium phosphate,
	Phosphorescent calcite.
Zinc silicate,	Sodium uranyl cobalt acetate.
Zinc sulphate,	Sodium molydate.

The following substances were practically unaffected by ultraviolet excitation:

Barium chloride,	Cesium chloride,	Sodium chloride,
Barium sulphate,	Didymium chloride,	Sodium silicate,
Beryllium chloride,	Lead chloride,	Telluric acid,
Calcium fluospar,	Naphthol yellow,	Thallun sulphate,
Calcium sulphate,	Potassium iodide,	Tungstic acid,
Cadmium iodide,	Rubidium chloride,	Vanadium chloride,

and the oxides:

Al <sub>2</sub> O <sub>3</sub> ,	CaO,	Cr <sub>2</sub> O <sub>3</sub> ,	PbO,	NiO,	SiO,	UO <sub>3</sub> ,
BaO,	CeO <sub>2</sub> ,	CuO,	MgO,	Ni <sub>2</sub> O <sub>2</sub> ,	SnO <sub>2</sub> ,	ZnO.
Bi <sub>2</sub> O <sub>3</sub>	CeO,	FeO,	MnO,	Sb <sub>2</sub> O <sub>3</sub> ,	TeO <sub>2</sub> ,	

Three general types of excitation were observed. First, a broad continuous region of excitation, somewhat variable in intensity and becoming gradually weaker further out in the ultraviolet. Second, strong in the violet and near ultraviolet to about 350 m $\mu$  where the fluorescence seems to dissappear over about 25 m $\mu$  then to reappear over a region about 100 m $\mu$  long with a maximum at about 275 m $\mu$ . Third, strong in the violet and near ultraviolet to about 350 m $\mu$  where the intensity drops very rapidly to practically zero in some cases or to a relatively small value beyond which point the intensity gradually fades away. No fluorescence was observed beyond 200 m $\mu$ . Anthracene is a good example of the first type, calcium tungstate and fluorescein are good examples of the second type, and the uranyl compounds illustrate the third type.

Photographs were obtained of the fluorescent light emitted from nearly all of the substances listed above which show any appreciable effect. The means of mounting the material is described in the following paragraph. It was very difficult to secure good photographs in some cases, particularly with the liquid solutions of fluorescein and eosin. The Fuess spectrograph was used and a camera lens of 7 inches focal length. Exposures ranging from one minute to thirty minutes were necessary.

#### METHOD OF MOUNTING THE FLUORESCENT SUBSTANCE.

It was necessary to have the fluorescent material offer a smooth surface to the exciting light in order to obtain a good record on the photographic plate, to which end the following simple method was used. A strip of varnish or glue about two centimeters wide was made across the whole width of the plate, and the powdered substance was sprinkled over this with sufficient depth to cover it completely. Another glass plate was then used to press upon and rub this surface till it was made as smooth as possible. Care was taken not to leave any part of the surface in a matte white condition due to rubbing, as such a part may appear on the photograph to be different from its surroundings. In case of some of the uranyl salts the natural crystals are very hard to reduce to fine enough granulations to make a smooth surface possible in this way. Some of the photographs show this. In case of liquids or solutions a strip of quartz was used, and it was mounted in such a way as to cover the portion of liquid to be exposed.

#### FURTHER STUDY OF THE URANYL COMPOUNDS.

It was mentioned above that the uranyl compounds were excited to fluorescence by wave-lengths of light lying between  $550\text{ m}\mu$  and  $350\text{ m}\mu$ . (Excitation by shorter wave-lengths than this was very feeble, too faint indeed to be photographed.) In the most intense part of the excitation, as photographed by the Fuess spectrograph, there appears to be a short region in which the excitation is variable, giving what might be called bands, and this region is the same as that in which absorption bands for these same materials are found. Now fluorescence is undoubtedly due primarily to absorption, though it cannot be assumed that greater absorption will produce proportionately greater fluorescence. It seems reasonable nevertheless to expect that there may be some variation in the excitation where there is variable absorption. If it is true that the variation in the intensity of the fluorescence is due to the changing absorption of the dispersed exciting light, this method might well be used in detecting and studying the absorption of materials, for if light of a



particular wave-length is absorbed and this excites fluorescence which emanates from the same, or neighboring, spot, it would be very easy to observe this photographically in case there is good dispersion of the exciting light. The work that follows is an attempt first to test the validity of the assumption by seeing if fluorescence bands *do* occur where absorption bands are known to exist, and, if the results confirm the assumption, to locate the position of as many absorption bands as this method is capable of giving, and thereby to test the laws which have been found to govern the arrangement of the bands previously observed. The uranyl salts are particularly good for this work because they give many narrow bands, both in the fluorescence region of the spectrum and in the absorption region.

THE FOLLOWING ARE THE COMPOUNDS TESTED:

- |                                  |                               |
|----------------------------------|-------------------------------|
| 1. Barium uranyl acetate,        | 7. Cesium uranyl chloride,    |
| 2. Lithium uranyl acetate,       | 8. Potassium uranyl chloride, |
| 3. Mercury uranyl acetate,       | 9. Potassium uranyl nitrate,  |
| 4. Strontium uranyl acetate,     | 10. Rubidium uranyl nitrate,  |
| 5. Uranyl acetate,               | 11. Cesium uranyl sulphate,   |
| 6. Sodium copper uranyl acetate, | 12. Rubidium uranyl sulphate. |

Nichols and Howes<sup>1</sup> in their recent treatise entitled "Fluorescence of the Uranyl Salts" give a summary of results showing the distribution and character of the fluorescence spectrum and the absorption spectrum of many uranyl compounds. It is shown that the spectrum of the fluorescent light consists of bands which naturally form eight groups of five members each, approximately, ranging from 640  $m\mu$  to 490  $m\mu$ , or thereabouts. The absorption spectrum consists also of bands having about the same arrangement, but ranging from 490  $m\mu$  to 380  $m\mu$ , apparently a continuation of the fluorescence spectrum. The frequency intervals (reciprocal wave-length intervals) between homologous bands of each group are practically the same throughout the spectrum of either, the interval being about 86 in the fluorescence spectrum and about 70 in the absorption spectrum. The last member of the fluorescence series is usually coincident with or at a distance from the first member of the absorption series of the homologous band of 86 or 70 frequency units. Considering all of the series of the various homologous bands there is an overlapping of the fluorescence and absorption spectra of about three groups, called the "reversing region" because here there are coincidences of fluorescence and absorption bands.

In this work a glass-bulb nitrogen-filled tungsten lamp, running at 6 amperes, was used as a source of ultraviolet light. A quartz mercury

<sup>1</sup> Nichols and Howes, Carnegie Inst. Wash. Pub., No. 298, 1919.

lamp was used<sup>1</sup> for calibration purposes, the calibration spectrum being photographed alongside of the other spectrum by exposing an adjacent portion of the slit of the spectrograph, both exposures taking place at the same time.

The intensity of blackening of the plates was measured by means of a device set up by J. O. Perrine in connection with his work<sup>2</sup> on "A Spectro-

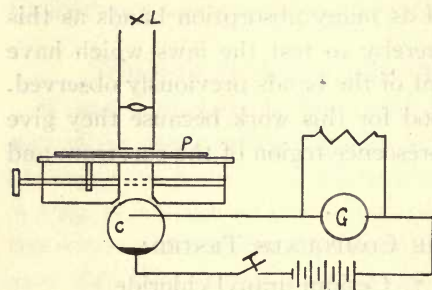


Fig. 2.

graphic Study of Ultraviolet Fluorescence Excited by X-rays." The apparatus makes use of a photo-electric cell, *C* in Fig. 2, and a sensitive galvanometer *G*. The cell, which was selected after trial of several types, was made by Kunz.<sup>3</sup> A Leeds and Northrup type *C* galvanometer was used about 6 meters from the scale near the comparator and cell. The comparator carried the photographic plate *P* just under a slit 2 mm. by .25 mm., through which a strong beam of light from an incandescent lamp *L* was passed. The lamp had one filament carrying a current of about 6 amperes from a storage battery. The current could be adjusted to meet the needs of the plate. *E* is a constant potential dry battery of about 80 volts. Further description of the apparatus is given in the paper just cited.

Much of the success of the present work is due to this apparatus. The instrument, which is highly sensitive to any variation in the density of the photographic image, has many advantages over other methods such as those depending on the eye, but faulty places in the photograph must be carefully avoided or eliminated by comparison with other photographs.

#### METHOD OF PLOTTING.

Curves were first made from the galvanometer deflections and the positions on the comparator. The intensities of the light transmitted by the negative were plotted as ordinates and the comparator readings as abscissæ, these plots being made while the measurements were being made, *i.e.*, plotting rather than recording the numbers. The intensities are merely relative, so that a convenient arbitrary scale was chosen to represent them. The positions of the mercury lines were located on the

<sup>1</sup> The well-known, yellowish green fluorescence of these substances is of a color to which most photographic plates do not respond well. The most satisfactory of the numerous plates tested was found to be the polychrome plate made by the Eastman Kodak Company.

<sup>2</sup> J. O. Perrine; Thesis in M.S. in Cornell University Library.

<sup>3</sup> Kunz and Stebbins, *PHYSICAL REVIEW*, 7, p. 282.



plot by observing the comparator reading for the smallest deflection of the galvanometer; thus the densest part of the line was taken as the proper position of the line. A setting could be made to the nearest tenth of a millimeter. Five to seven mercury lines were thus located on each plot. Knowing their wave-lengths to four significant figures their reciprocals were plotted (on another sheet) as ordinates against their recorded positions on the plot as abscissæ, and thus a calibration plot was obtained, giving the reciprocal wave-lengths for any comparator reading on the first plot. Using this calibration plot the final plot was obtained where the intensities of the light were plotted against the reciprocal wave-lengths. A new calibration plot was used whenever the mercury lines were found to be spaced differently due to different magnifications caused either by a change in the settings of the spectrograph or by a change in the camera adjustment. Final curves were made in this way for each of the twelve uranyl compounds.

In these plots a millimeter represents 2.5 frequency units,<sup>1</sup> and one tenth of a millimeter on the photographic plate. The accuracy of the data recorded in Tables I. to V. is such that the results are probably correct to within three frequency units. An estimated "probable error" is near one frequency unit. Typical curves are presented, greatly reduced, in Figs. 3, 4, 5 and 6.

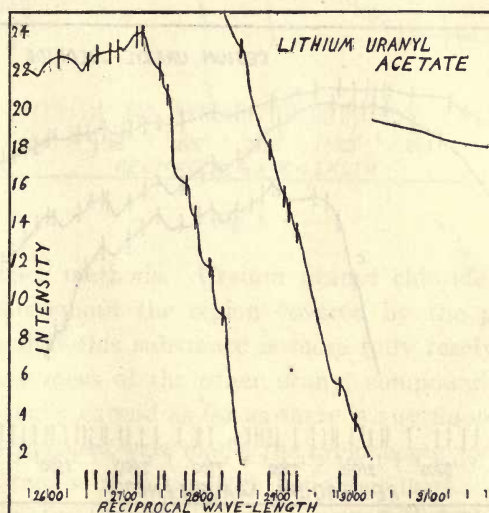


Fig. 3.

<sup>1</sup>A frequency unit is such that 500  $\mu\mu$  corresponds to 2000 frequency units, *i.e.*,

$$\frac{1}{.000000500 \text{ in meters}} = 2000 \times 10^3.$$

Peaks in the curves represent regions of greater fluorescence. They are undoubtedly regions of greater absorption, and many of them coincide with absorption bands of these substances that have been located by

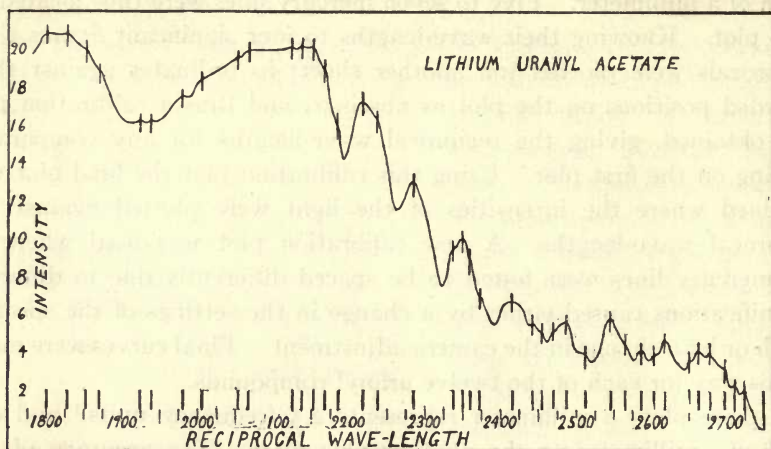


Fig. 4.

other methods. The data in the tables are arranged in two columns so as to show the agreement of the results obtained by this method and measurements made by other methods. The first column shows the

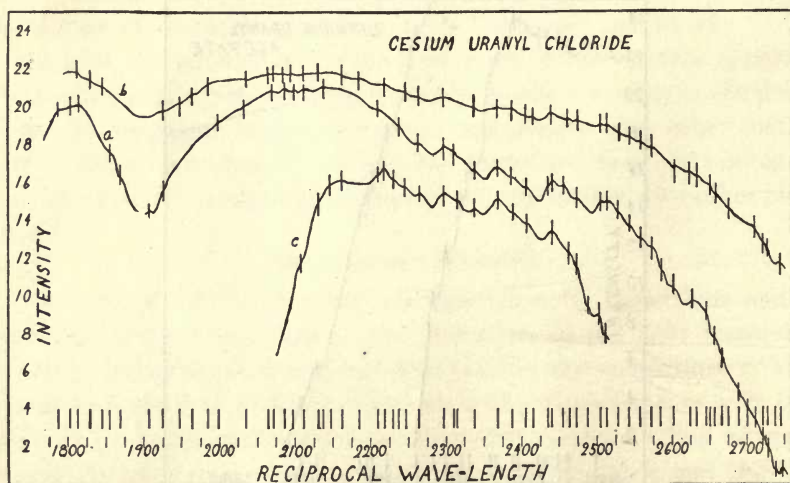


Fig. 5.

former, the second column the latter as published by Nichols and Howes. The photo-electric cell is so sensitive as to detect bands that are not apparent to the unaided eye. Data for these fainter bands seem to check



equally well, therefore credence is given to these also. Wherever there is a marked difference in the direction of the curve such as to indicate a partially resolved band and wherever the main part of an unresolved band appears there is a short vertical line drawn through the curve, and these lines appear again at the bottom of the plot. The bands have been designated by the same symbols used by Nichols and Howes. In cases where bands could not be identified, symbols were assigned so as to agree as nearly as possible with those of the same class, *e.g.*, the acetates, nitrates, etc.; as determined by Nichols and Howes.

#### EXTENSION OF THE ABSORPTION REGION.

Some of the photographs show very distinctly that the absorption bands extend further into the ultraviolet region than it has been possible

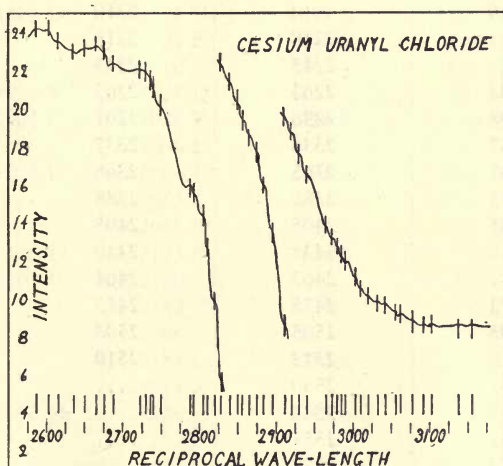


Fig. 6.

to go by the other methods. Cesium uranyl chloride is particularly rich in bands throughout the region covered by the photograph. It has been known that this substance is more fully resolved at ordinary temperatures than most of the other uranyl compounds. In order to see if the bands really extend as far as there is any fluorescence excited, a few long-time exposures were made, the range being  $390\text{ m}\mu$  to  $310\text{ m}\mu$ . A quartz-bulb nitrogen-filled tungsten lamp was used. An exposure of two hours was found to be sufficient to register all of the bands that could be recorded by the photographic plate. Further exposure only made the black part of the plate darker and made the detection of the bands by the photo-electric cell more difficult. In fact it was necessary to have regard to the time of exposure in all cases in order to obtain proper

TABLE I.

*Bands Appearing in Two or More Curves for Cesium Uranyl Chloride.*Range 550  $m\mu$  to 370  $m\mu$ , approximately. See Fig. 5.

	Curve a, $\text{\AA.}$	Curve b, $\text{\AA.}$	Curve c, $\text{\AA.}$	Curve on Fig. 6.
B <sub>1</sub>	1812	1810	....	
D	1925	1925	....	
E <sub>2</sub> '	2032	2035	....	
d	2070	2072	....	
d'	2086	2085	....	
e <sub>2</sub> '	2098	2095	....	
b	2113	2113	....	
b <sub>3</sub>	....	2131	2130	
d	....	2148	2145	
d <sub>2</sub> ''	....	2162	2162	
d'	2210	....	2210	
d	....	2218	2218	
e <sub>2</sub> ''	....	2245	2245	
b <sub>2</sub> '	2263	2263	2265	
d <sub>2</sub> '	2298	2296	2297	
b <sub>2</sub>	2337	2336	2337	
d <sub>2</sub>	2367	2365	2368	
e <sub>2</sub> ''	2385	2388	2388	
b <sub>2</sub> '	2405	2405	2405	
d <sub>2</sub>	2440	2438	2440	
a <sub>1</sub> '	....	2462	2464	
b <sub>2</sub> '	2473	2475	2473	
d <sub>2</sub> '	2505	2505	2503	
d <sub>2</sub>	2512	2512	2510	
e <sub>2</sub> ''	2528	2530	....	
b <sub>2</sub> '	2543	2543	....	
b <sub>3</sub>	2557	2557	....	
d <sub>1</sub> ''	2572	2572	....	
d <sub>2</sub>	2586	....	....	2586
e <sub>2</sub> ''	2600	2602	....	2602
c	....	2632	....	2633
d	....	2650	....	2650
e	2657	2657	....	....
a	....	2675	....	2675
b <sub>2</sub> '	2687	....	....	2686
d <sub>1</sub> ''	2712	2710	....	....
d	2722	2722	....	2722
e	2730	2728	....	....

sensitiveness in measuring the plates. Too long exposures tend to fill up the places between the bands and destroy the contrast.

All of the twelve compounds were photographed for the range 390  $m\mu$  to 310  $m\mu$ , measurements were made, and the data plotted in the same manner as in the case of the first range. Since the first range extended



from about  $550\text{ m}\mu$  to  $370\text{ m}\mu$ , there was an overlapping of about  $20\text{ m}\mu$ . This repetition aided in establishing the reality of the bands. Only for cesium uranyl chloride were there independent measurements made with the photo-electric cell from different photographs over the first range. These are plotted on the same sheet (Fig. 5). There is also a curve to show the effect of placing a screen between the substance and the plate

TABLE II.

Barium Uranyl Acetate.		Lithium Uranyl Acetate.		Uranyl Acetate.	
B. Values of $1/\lambda$ .	N. & H. Values of $1/\lambda$ , p. 161, 167.	B. Values of $1/\lambda$ .	N. & H. Values of $1/\lambda$ , p. 158, 164.	B. Values of $1/\lambda$ .	N. & H. Values of $1/\lambda$ , p. 149.
1805 I		1800 A		1788 E <sub>1</sub>	1791 E <sub>1</sub>
1830 D	1828 D	1827 C	1825 C	1803 F	1802 F
1862 H		1852 F	1852 F	1820 G	1817 G
1888 I		1870		1860 B	1857 B
1925 E	1923 E	1924 D		1913 H	1912 H
1943 G	1942 G	1938 F	1936 F	1965 E	1965 E
1975 I		1980 I		1988 G	1989 G
2018 F	2017 F	2005 D	2005 D	2028 B	2029 B
2032 H		2052 h		2039 C'	2039 C'
2070 C		2068 h'		2053 F <sub>1</sub>	2056 F <sub>1</sub>
2085 D	2086 D	2125 h	2124 h	2075 G	2073 G
2100 F	2101 F	2138 h'		2088 H	
2125 G'		2152 c'		2100 e'	
2155 c		2168 c		2120 f'	
2210 g'		2185 e	2185 e	2150 d	
2245 e'		2219 c'		2173 e'	
2275 gh	2276 gh	2238 c	2235 c	2210 i	
2305 c''		2285 c		2215 g	
2345 gh		2338 h		2223 d	
2365		2350 h'		2260 f'	
2395 e	2394 e	2360 c'		2270 k	
2420 gh	2419 gh	2373 c	2373 c	2281 i	
2450 f'		2415 h'		2303 c	
2475 g		2443 c	2446 c	2315 e'	
2488 gh	2487 gh	2455 f		2323 e	
2502 c		2470 e		2340 k	
2520 f'		2488 h'		2353 d	
2530 e''		2513 c	2515 c	2388 f	
2548 g		2545 h		2412 k	
2560 gh		2565 c		2445 c	
2568 c'		2586 c	2585 c	2465 e	
2578 c		2603 g		2490 i	
2600 e''		2610 e		2503 d	
2615 g		2618 h		2518 c	
2626 h'		2635 c		2538 e	
2632 gh		2650 c		2547 f'	

TABLE II.—*continued.*

Barium Uranyl Acetate.		Lithium Uranyl Acetate.		Uranyl Acetate.	
B. Values of $1/\lambda$ .	N. & H. Values of $1/\lambda$ , p. 161, 167.	B. Values of $1/\lambda$ .	N. & H. Values of $1/\lambda$ , p. 158, 164.	B. Values of $1/\lambda$ .	N. & H. Values of $1/\lambda$ , p. 149.
2665 e'		2663 c		2557	
2688 g		2678 e		2563 i	
2707 c'		2688 h		2576 d	
2728 f'		2698 h'		2585 c	
2738 e'		2711 c'		2593 e'	
2748 e		2724 c		2602 f	
2757 g		2743 g		2607 e'	
2770 gh		2750 e		2618 f'	
2790 c''		2778 c		2633 i	
2805 e'		2790 c		2638 g	
2815 e		2810 g		2653 c	
2843 gh		2828 h		2675 e	
2855 c		2850 c'		2680 x	
2867 f'		2889 e		2690 f'	
2877 e'		2907 h'		2697 k	
2888 e		2915 c		2708 g	
2905 h'		2925 c		2718 d	
2922 c'		2982 c		2740 f	
2930 c''		3003		2748 x	
2943 e'				2763 k	
2978 gh				2777 g	
2995 c				2789 d	
3030 e				2813 e	
3085 e'				2825 f'	
3122 c'				2838 k	
3148 f'				2848 g	
				2880 e	
				2923 d	
				2948 e	
				2973 k	
				3028 x	
				3057 g	
				3075 d	
				3118 k	
				3128 g	
				3143 d	
				3165 x	

with the hope of screening off some of the visible light diffusely reflected from the substance. This procedure was however not satisfactory. One purpose of the three plots (or curves) for cesium uranyl chloride is to show how well the bands check. The data are given in Table I. Bands that appear in two or more curves are given in parallel columns. It can be seen that the differences are few in number and are well within the experimental error.



## DISCUSSION OF RESULTS.

In Tables II. to V. comparison is made with former data obtained when the substance was at the temperature of liquid air,  $-185^{\circ}\text{C}$ . This seems justifiable because of the fact that some of the compounds are partially resolved at room temperature, so that the components, which are separated quite well by the relatively large dispersion of the spectrograph, show up well when measured by the photo-electric cell.

A comparison of the results obtained by the present method with those of other methods seems to establish the fact that *the position of the absorption bands can be determined by the fluorescence that the absorption gives rise to*, a fact already established by Howe<sup>1</sup> in the case of certain phosphorescent sulphides. Not all absorption bands may have the

TABLE III.

Potassium Uranyl Nitrate.		Potassium Uranyl Chloride.		Rubidium Uranyl Sulphate.	
B. Values of $\frac{1}{\lambda}$ .	N. & H. Values of $\frac{1}{\lambda}$ , p. 139.	B. Values of $\frac{1}{\lambda}$ .	N. & H. Values of $\frac{1}{\lambda}$ , p. 90-93.	B. Values of $\frac{1}{\lambda}$ .	N. & H. Values of $\frac{1}{\lambda}$ , p. 174, 178.
1795 D	1794 D	1761		1810 I	1812 I
1823 I	1824 I	1787 A <sub>1</sub>	1785 A <sub>1</sub>	1822 A'	
1860 B	1862 B	1815 C <sub>1</sub>	1816 C <sub>1</sub>	1842 C	1844 C
1978 E	1976 E	1945 E <sub>2</sub> '	1940 E <sub>2</sub> '	1872 F	1872 F
2005 J	2007 J	1987 C <sub>2</sub>	1988 C <sub>2</sub>	1907 A'	1908 A'
2070 F	2069 F	2012 d <sub>3</sub>	2014 d <sub>3</sub>	1948 E	1947 E
2093		2085 d <sub>3</sub>		1957 F	1955 F
2127 d		2155 d <sub>3</sub>	2155 d <sub>3</sub>	1990 A'	1992 A'
2162 f		2237 e <sub>2</sub> '		2012 C	2011 C
2188 l'		2268 c <sub>2</sub> '	2264 c <sub>2</sub> '	2063 b <sub>1</sub>	2066 b <sub>1</sub>
2268 d	2269 d	2335 c <sub>2</sub> '	2333 c <sub>2</sub> '	2078	
2337 d		2375 e <sub>2</sub> '	2375 e <sub>2</sub> '	2093 e <sub>1</sub>	2096 e <sub>1</sub>
2372 f	2369 f	2390 a	2392 a	2133 b <sub>1</sub>	2137 b <sub>1</sub>
2394 l'	2397 l'	2456 a <sub>1</sub>	2456 a <sub>1</sub>	2165 e <sub>1</sub>	
2425 j		2468 c <sub>2</sub>		2190 g	2188 g
2450 k		2477 c <sub>2</sub> '		2205 b <sub>1</sub>	2206 b <sub>1</sub>
2492 j		2530 a <sub>2</sub> ''	2533 a <sub>2</sub> ''	2238 e <sub>1</sub>	
2522 k		2548 c <sub>2</sub> '		2268 h	2267 h
2535 l'		2595 a <sub>1</sub>	2595 a <sub>1</sub>	2282 c <sub>1</sub>	
2563 j		2613 c <sub>2</sub> '		2300 d	2301 d
2580 f		2626 d <sub>1</sub>		2322 g <sub>1</sub>	2322 g <sub>1</sub>
2605 l'		2655 e <sub>2</sub> '		2340 h	2341 h
2618 d		2665 a <sub>1</sub>		2375 e <sub>1</sub>	2375 e <sub>1</sub>
2637 j		2675 c <sub>2</sub>		2410 h	2409 h
2655 f		2698 d <sub>1</sub>		2420 b <sub>1</sub>	
2675 l'		2726 e <sub>2</sub> '		2430 c	
2703 j		2737 a <sub>1</sub>		2450 e <sub>1</sub>	2450 e <sub>1</sub>
2722 f		2755 c <sub>2</sub> '		2482 h	
2745 l'		2782 d <sub>3</sub>		2498 c <sub>1</sub>	

<sup>1</sup> Trans. Am. Philos. Soc., LVI., p. 259 (1917).

TABLE III.—*continued.*

Potassium Uranyl Nitrate.		Potassium Uranyl Chloride.		Rubidium Uranyl Sulphate.	
B. Values of $\lambda$ .	N. & H. Values of $\lambda$ , p. 139.	B. Values of $\lambda$ .	N. & H. Values of $\lambda$ , p. 90-93.	B. Values of $\lambda$ .	N. & H. Values of $\lambda$ , p. 174, 178.
2757 d		2800 b <sub>1</sub> '		2522 e <sub>1</sub>	
2798 k		2807 a <sub>1</sub>		2550 h	
2813 l'		2818 c <sub>2</sub>		2572 c	
2853		2835 d <sub>1</sub>		2585 d	
2883 l'		2850 d <sub>3</sub>		2606 g <sub>1</sub>	
2898 d		2876 a <sub>1</sub>		2622 h	
2915 j		2887 c <sub>2</sub>		2637 c <sub>1</sub>	
2928 f		2898 c <sub>2</sub> ''		2653 d'	
2953 l'		2918 d <sub>3</sub>		2667 e <sub>1</sub>	
2983 j		2939 b <sub>1</sub> '		2680 g	
3032 d		2950 c <sub>2</sub>		2705 c <sub>1</sub>	
3050 j		2968 c <sub>2</sub> ''		2715 c	
3075 k		2998 e <sub>2</sub> '		2724 d	
3100 d		3018 a <sub>1</sub>		2738 e <sub>1</sub>	
		3042 d <sub>1</sub>		2745 g <sub>1</sub>	
		3080 b <sub>1</sub> '		2757 h <sub>1</sub>	
		3100 c <sub>2</sub> '		2782 c <sub>1</sub>	
		3128 d <sub>3</sub>		2803	
		3151 a		2820 g	
				2838 b <sub>1</sub>	
				2855 c	
				2898 h <sub>1</sub>	
				2915 c <sub>1</sub>	
				2930 c	
				2949	
				2978 b <sub>1</sub>	
				3000 c	
				3040 h <sub>1</sub>	

power of exciting fluorescence, and, if so, such bands would not appear on the plate. This may explain why some bands are missing by this method. Most of the known bands do appear however and many more besides. Where formerly the absorption spectrum was observed only between  $490\text{ m}\mu$  and  $380\text{ m}\mu$ , approximately, *the range is extended by this method in both directions, i.e.,  $550\text{ m}\mu$  to  $322\text{ m}\mu$ , or through a frequency range of 1800 to 3100.* In the extension toward the shorter wavelengths the bands readily fall into the series already determined, a fact which strengthens the belief that all regions showing fluorescence really serve to locate absorption bands.

In a few instances there seemed to be a new series starting somewhere near the middle of the complete absorption region, but more observations are needed to establish this if such is the case. Series of this sort are



indicated by letters in the latter part of the alphabet. Again, there is some indication that the intensity of the members of the series varies as we go through the spectrum, resulting in more than one maximum. If this is true it may explain the apparent omission of a part of the series due to the faintness of the bands, as can be noted in some cases.

### REVERSING REGION.

The so-called reversing region lies within the seventh, eighth and ninth groups of the fluorescent spectra, *i.e.*, 2,000 to 2,200 frequency units

TABLE IV.

Cesium Uranyl Sulphate.		Strontium Uranyl Acetate.		Sodium Copper Uranyl Acetate.	Mercury Uranyl Acetate.	Rubidium Uranyl Nitrate.
B. Values of $1/\lambda$ .	N. & H. Values of $1/\lambda$ , p. 175, 178.	B. Values of $1/\lambda$ .	N. & H. Values, p. 160, 166.			
1795 E	1794 E	1810		1820 C	1798 A	1788 D
1815 G	1813 G	2000 D	2004 D	1873 B	1812 B	1807 F
1845 B	1848 B	2050 H	2046 H	1975 A	1885 B	1840 K
1864 C	1861 C	2128 h'		2000 D	1980 C	1852 L
1903 G		2200 h'	2206 h'	2040 B	2015 c'	1910 I
1915 I	1913 I	2270 h	2274 h	2080 C	2030 c	1923 K
1952 D	1954 D	2287		2100 f	2085 c'	1960 D
1990 H	1993 H	2302 j		2128 b	2150 h	2045 D
2018 i		2337 h'		2152 h	2200 g	2095 K
2035 c'	2036 c'	2350 i	2350 i	2205 g	2218 h	2120 I'
2050 E	2052 E	2400 e''	2400 e''	2263 f <sub>1</sub>	2252 e	2193 I'
2063 f	2061 f	2437 a		2275 g	2320 e	2218 $\delta$
2080 h	2077 h	2516 j		2300 h	2365 c'	2270 d
2087 i	2085 i	2544 h'		2340 g	2405 h'	2295 h
2102 c	2104 c	2578 a		2365 h	2427 h	2338 d
2138 g		2613 h'		2410 g	2455 d	2360 $\delta$
2147 g'	2144 g'	2655 j		2420 i	2493 i	2375 f
2165 a	2165 a	2680 e''		2473 f <sub>1</sub>	2514 c	2390 l
2192 e		2695 h		2538 f <sub>1</sub> '	2532 e	2402 I'
2222 g'		2718 a		2564 i	2563 i	2432 h
2232 a		2732 b		2573 h	2590 f	2473 I'
2280 g	2280 g	2770 i		2590 f	2602 e	2505 h
2290 g'		2799 b'		2605 f <sub>1</sub> '	2622 g	2527 l
2307 a		2811 c		2620 g	2633 i	2550 d
2320 c'		2820 e''		2627 g'	2660 f	2570 $\delta$
2352 g		2835 h		2632 i	2677 f <sub>1</sub>	2585 f
2372 a		2875 b		2655 c'	2703 i	2595 l
2405 e		2903 h		2660 f	2707 h	2618 d
2428 g'	2427 g'	2928 a		2675 f <sub>1</sub> '	2722 c	2626 e
2460 c'		2945 b		2680 f <sub>1</sub>	2732 f	2635
2480 e'		2965 h'		2688 g	2738 d	2649 x
2500 g'	2498 <sup>1</sup>	2975 h		2703 i	2755 h'	2655 f
2530 c'		3010 b'		2713 h	2770 c <sub>1</sub>	2660 k

<sup>1</sup> No letters assigned.

TABLE IV.—*continued.*

Cesium Uranyl Sulphate.		Strontium Uranyl Acetate.		Sodium Copper Uranyl Acetate.	Mercury Uranyl Acetate.	Rubidium Uranyl Nitrate.
B. Values of $1/\lambda$ .	N. & H. Values of $1/\lambda$ , p. 175, 178.	B. Values of $1/\lambda$ .	N. & H. Values, p. 160, 166.			
2543 e	2543 <sup>1</sup>	3020 c		2728 f	2780 h	2670 l
2550 e'		3093 c		2753 f <sub>1</sub>	2799 f	2680 l'
2568 g'	2567 <sup>1</sup>			2770 i	2823 f <sub>1</sub>	2698 e
2578 i				2780 h	2835 g	2712 h
2595 c				2793 c'	2850 h	2730 k
2605 d <sub>1</sub>				2813 f <sub>1</sub> '	2898 h'	2743
2615 e	2613 <sup>1</sup>			2835 g'	2910 c <sub>1</sub>	2750 l'
2626 f'				2850 h	2921 h	2755 d
2643 g'				2863 c'	2960 f <sub>1</sub>	2770 e
2675 d <sub>1</sub>				2876	2978 c <sub>1</sub>	2780 S
2692 e'				2903 g'	3015 f	2802 k
2703 g				2922 h	3050 c <sub>1</sub>	2822 l'
2726 a				2934 f	3170 f <sub>1</sub>	2827 d
2756 e				2968 g		2835 e
2770 g				3005 f		2859 x
2789 i				3040 g'		2865 f
2820				3068 c'		2870 k
2850 g'				3097 f <sub>1</sub>		2898 d
2874 c				3168 f <sub>1</sub>		2925 h
2885 d <sub>1</sub>						2939 k
2906 e'						2953
2920 g'						2965 d
2928 i						2988 S
2947 c						3002 x
2975 e'						3010 k
2993 g'						3028 l'
3001 i						3045 e
3026 d <sub>1</sub>						3075 f
3052 g						3089 l
3068 i						3118 e
3133 g'						3139 x
3168 d <sub>1</sub>						3150 k
						3173 l'

approximately. This region is extended further toward the long wave lengths if credence is given to the bands herein contained and if these bands are due to absorption, for, if any point on the plate containing the fluorescent material is being excited to fluorescence by the absorption of light of a particular wave-length, this absorption being due to the fluorescent material itself, there is evidently a reversal wherever the wave-length of the exciting light is equal to the wave-length of a band of the fluorescence spectrum. In the tables there are shown several bands agreeing well with the bands of the fluorescence spectra, *i.e.*, as well as



TABLE V.

*Cesium Uranyl Chloride.*

B. Values of $\tau/\lambda$ .	N. & H. Values of $\tau/\lambda$ , p. 90-93.	B. Values of $\tau/\lambda$ con.	N. & H. Values of $\tau/\lambda$ .	B. Values of $\tau/\lambda$ con.
1785 E <sub>2</sub> '		2405 b <sub>2</sub> '	2405 b <sub>2</sub> '	2788 d <sub>2</sub> '
1812 B <sub>1</sub>	1810 B <sub>1</sub>	2409 b <sub>2</sub>	2410 b <sub>2</sub>	2793 d <sub>2</sub>
1828 C	1828 C	2415 b <sub>3</sub>	2416 b <sub>3</sub>	2804 e <sub>2</sub> '
1845 D <sub>1</sub>	1843 D <sub>1</sub>	2435 d <sub>2</sub> '	2436 d <sub>2</sub> '	2810 e <sub>2</sub> ''
1855 D <sub>2</sub> '	1854 D <sub>2</sub> '	2440 d <sub>2</sub>	2441 d <sub>2</sub>	2819 b
1868 E <sub>2</sub> ''	1866 E <sub>2</sub> ''	2455 e <sub>2</sub>		2828 b <sub>2</sub> '
1906 B <sub>3</sub>		2462 a <sub>1</sub> '		2839 b <sub>3</sub>
1924 D	1924 D	2474 b <sub>2</sub> '	2476 b <sub>2</sub> '	2850 d
1950 E <sub>2</sub> ''	1950 E <sub>2</sub> ''	2489 c		2857 d <sub>2</sub> '
1963 A <sub>2</sub>	1964 A <sub>2</sub>	2505 d <sub>2</sub> '	2509 d <sub>2</sub> '	2865 d <sub>2</sub>
1985 B <sub>2</sub>	1985 B <sub>2</sub>	2512 d <sub>2</sub>	2513' d <sub>2</sub>	2874 e <sub>2</sub> '
1998 C <sub>1</sub>	1998 C <sub>1</sub>	2528 e <sub>2</sub> ''	2530 e <sub>2</sub> ''	2884 e <sub>2</sub> ''
2032 E <sub>2</sub> '	2030 E <sub>2</sub> '	2543 b <sub>2</sub> '		2895 b <sub>2</sub> '
2065 c	2064 c	2557 b <sub>3</sub>		2911 c
2070 d'	2071 d'	2572 d <sub>1</sub> ''		2920 d
2085 d <sub>2</sub> '	2086 d <sub>2</sub> '	2586 d <sub>2</sub>	2585 d <sub>2</sub>	2930 d <sub>2</sub> '
2098 e <sub>2</sub> '	2100 e <sub>2</sub> '	2601 e <sub>2</sub> ''		2940 d <sub>2</sub> ''
2107 a		2615 b <sub>2</sub> '		2966 b <sub>2</sub> '
2113 b	2114 b	2625 b <sub>3</sub>		2973 b <sub>2</sub>
2131 b <sub>3</sub>	2132 b <sub>3</sub>	2632 c		2980 b <sub>3</sub>
2137 c <sub>1</sub> '	2135 c <sub>1</sub> '	2645 d <sub>2</sub> '		2984 c
2147 d	2146 d	2650 d <sub>2</sub>		2990 d
2162 d <sub>2</sub> ''	2164 d <sub>2</sub> ''	2657 e		3003 d <sub>2</sub>
2185 b	2184 b	2665 e <sub>2</sub> ''	2670 e <sub>2</sub> ''	3010 d <sub>2</sub> ''
2210 d'	2212 d'	2675 a	2674 a	3020 e <sub>2</sub> ''
2218 d		2680 b		3032 b
2230 d <sub>2</sub>	2229 d <sub>2</sub>	2687 b <sub>2</sub> '		3043 b <sub>2</sub>
2238 e <sub>2</sub> '	2239 e <sub>2</sub> '	2693 b <sub>2</sub>		3055 c
2245 e <sub>2</sub> ''	2245 e <sub>2</sub> ''	2702 c		3062 d
2263 b <sub>2</sub> '	2263 b <sub>2</sub> '	2712 d		3077 d <sub>2</sub> ''
2297 d <sub>2</sub> '	2296 d <sub>2</sub> '	2722 d <sub>2</sub>		3092 e <sub>2</sub> ''
2310 e	2310 e	2730 e		3102 b
2315 e <sub>2</sub>	2314 e <sub>2</sub>	2736 e <sub>2</sub> '		3137 d <sub>2</sub> '
2337 b <sub>2</sub>		2740 e <sub>2</sub> ''		3155 e <sub>2</sub> '
2368 d <sub>2</sub>	2369 d <sub>2</sub>	2748 a		
2388 e <sub>2</sub> ''	2389 e <sub>2</sub> ''	2750 b		

the precision of the work warrants. These therefore indicate more reversals than have been heretofore obtained, and that the number of reversals in any one series is not limited to one, but may be as great as two or three.

It is rather curious that most of the new reversals are on the long wave-length side of the "reversing region" as given by Nichols and

Howes. In the cases of potassium uranyl chloride and rubidium uranyl sulphate none of the reversals by this method has been observed by other methods. This is true with cesium uranyl chloride, excepting the series  $E_2''$ . The methods give results that agree in series F of cesium uranyl sulphate. It must be admitted however that more data are needed in order to confirm or disprove the existence of the new reversals. In cases where several photographs were made for the same substance there is a close agreement between the independent measurements, so that one is convinced that the method is capable of giving results quite comparable with those obtained by other methods.

The following table (VI.) shows the reversals of the bands in the various substances studied. The wave numbers in the first column are from Tables II. to V., and those to the right are from the tables given by Nichols and Howes on the pages indicated. Values in parentheses indicate that the corresponding band of the fluorescence spectrum is missing, or that it is not recorded by them. References are also missing for mercury uranyl acetate, sodium copper uranyl acetate, and rubidium uranyl nitrate, and they are therefore not included in the table.

TABLE VI.

*Reversals of the Uranyl Bands.*

Reversals by Present Method.		Reversals Observed by Nichols and Howes.
Barium uranyl acetate		(Pages 161, 167)
Series D	reverses at 1830 and 2085	E reverses at 2009
F	" " 2018 " 2100	
Potassium uranyl chloride		(Pages 88-101)
Series E	" " 1925	
G	" " 1943	
(H)	" " (1862) " (2032)	
(I)	" " (1805) " (1888) and (1975).	
Lithium uranyl acetate		(Pages 158, 164)
F	reverses at 1852 and 1938	F' at 2105 reverses approximately with
C	" " 1827	f' at 2109.
D	" " 2005 " (1924)	
Strontium uranyl acetate		(Pages 160, 166)
D	reverses at 2000	
H	" " 2050	
Uranyl acetate		(Page 149)
E	reverses at 1788	
F'	" " 1803	
G	" " 1820, 1988 and 2075	
H	" " 1913 (2088)	
B	" " 1860, 2028	
E	" " 1965	
C'	" " 2039	
F'	" " 2053	



TABLE VI.—*continued.*

Cesium uranyl chloride			(Pages 88-101)		
E <sub>2</sub> ''	reverses at	(1785), 1868, 1950, 2032	B	reverses at	1974
B	" "	1812	C	" "	1993
C'	" "	1828	D	" "	2005
D'	" "	1845	E	" "	2026
D <sub>2</sub> '	" "	1855	A	" "	2037
D	" "	1924	E <sub>2</sub> '	" "	2030
A <sub>2</sub>	" "	1963	E <sub>2</sub> ''	" "	2034
B <sub>2</sub>	" "	1985			
C <sub>1</sub>	" "	1998			
A <sub>1</sub>	reverses at	1787	B	reverses at	1969
C <sub>1</sub>	" "	1815	C	" "	1984
E <sub>2</sub> '	" "	1943	D	" "	2004
C <sub>2</sub>	" "	1987	E	" "	2022
			A <sub>2</sub>	" "	2039
Potassium uranyl nitrate			(Page 139)		
D	reverses at	1794			
I	" "	1824			
B	" "	1862			
E	" "	1976			
J	" "	2007			
F	" "	2069			
Cesium uranyl sulphate			(Pages 173, 178)		
E	reverses at	1795	F	reverses at	2061
G	" "	1815, (1903)			
B	" "	1845			
C	" "	1864			
I	" "	1915			
D	" "	1952			
H	" "	1990			
F	" "	2063			
Rubidium uranyl sulphate			(Pages 174, 178)		
I	reverses at	1810	E <sub>1</sub>	reverses at	2028
A'	" "	(1822), 1907, 1990	F	" "	2038
C	" "	1842, 2012	G <sub>1</sub>	" "	2045
F	" "	1872, 1957			
E	" "	1948	G	" "	2049

## SUMMARY.

Fluorescence is excited by wave-lengths of light between 550 m $\mu$  and 200 m $\mu$ , approximately. The intensity and range of excitation depends upon the substance.

There are three types of excitation observed:

1. Continuous, but variable in intensity, between 550 and 200 m $\mu$ .
2. Continuous, but variable in intensity, between 550 and 350 m $\mu$ .
3. Discontinuous, exhibiting a gap between 350 and 325 m $\mu$ , otherwise like type i.

The range of the absorption spectra of twelve uranyl salts is extended to 550 m $\mu$  and to 320 m $\mu$  by the method herein discussed, a method

which makes use of the fluorescence excited by dispersed ultraviolet light, observing that wherever greater absorption takes place greater fluorescence results therefrom.

It is desirable to continue the work on the uranyl salts by this method, especially in the reversing region, because it is here that information can doubtless be obtained about the real mechanism of fluorescence.

The gap at 350 to 325  $m\mu$  in case of a few substances noted is rather curious. No explanation is given, but further study of this type of excitation is desirable. It was observed that one of the uranyl compounds, namely sodium uranyl cobalt acetate, appeared to the eye to give this type of excitation, but it was not studied photographically because of the relatively weak fluorescence produced.

The writer wishes to express his gratitude to Professor Ernest Merritt under whose guidance this work has been performed.

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